fMRI Evidence of Nested Networks Associated with Motor Tasks

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Introduction

A fundamental challenge in neuroscience is to relate phenomena occurring on one scale of activity with events occurring on other scales. To examine events on different scales, we modified a technique for weight-space representations used in computational neuroscience and applied it to functional neuroimaging. Our work was designed to test specific predictions about how motor networks may be organized across tasks and across scales (1). We hypothesized that networks of regional brain activity in the neocortex could be detected simultaneously across different orders of spatial magnitude and that some networks would be nested within other networks.

Method

Human motor data were examined from six motor tasks using fMRI at 1.5 T. For each hand, the tasks consisted of simple repetitive finger movements, complex alternating finger movements, and imagined complex alternating finger movements. Data were collected using the T_2* BOLD contrast method (2). Both static and time-course data were obtained by cross-correlation with a reference function, and time-averaged patterns of activity were generated for each task. Localized regions of interest (ROIs) averaged 1.0 cm^2 x 1 cm, with a maximum ROI = 3.5 cm^2 x 1.0 cm. Specific ROIs corresponded anatomically with the behavioral tasks. Cross-correlation analysis showed no objective evidence for large scale inter-connected networks among ROIs, either within or between tasks. Within the conceptual framework of modeling parallel distributed networks, we looked at how the connections among individual voxels encoded information across tasks. fMRI signal activity was used to determine weights between all pairs of voxels by summing the inner products of transformed signal intensity across tasks. No assumptions were made about anatomy or ROIs.

Results

The weight space maps revealed a fully connected network in the region of M1. A large, fully connected network also emerged with nodes at bilateral M1, bilateral S1 and supplementary motor cortex. This large network was approximately two orders of magnitude greater than the small networks nested within it at nodal points (large network 70 cm^2 x 1 cm; M1 ROI 1 cm^2 x 1 cm). There was no significant difference in the temporal dynamics at the two scales.

Conclusions

Our findings (i) suggest that some motor tasks activate brain regions at different scales, and (ii) support the notion that the neocortex is partially organized into dynamic networks that are nested within other networks at different scales of neural organization.

References

1. Sutton J. P., Anderson J. A. In: Bower, J. M. (ed) *Neurobiology of Computation.* Boston, Kluwer Academic. 1995, 317-322.
2. Bandettini P. A., Jesmanowicz A., Wong E. C., Hyde J. S. *Magn. Reson. Med.* 1993, 30: 161-173.